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AERODYNAMIC DATA FOR A WING SECTION OF THE REPUBLIC XF-12 AIRPLANE EQUIPPED WITH A DOUBLE SLOTTED FLAP

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MEMORANDUM REPORT

for the

Air Technical Service Command, Army Air Forces

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AERODYNAMIC DATA FOR A WING SECTION OF THE REPUBLIC XF-12 AIRPLANE EQUIPPED WITH A DOUBLE SLOTTED FLAP

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SUMMARY

An investigation was carried out in the Langley two-dimensional low-turbulence tunnels for the purpose of developing an optimum flap configuration for maximum lift on an airfoil section for the Republic XF-12 airplane equipped with a double slotted flap. Lift and flap loads were obtained at several flap deflections for two flap paths. Drag characteristics of the section with flaps retracted were also determined.

A maximum lift coefficient of 3.43 was measured for this airfoil-flap combination for a flap deflection of 60° at a Reynolds number of 14 million. An investigation of flap and fore flap configurations showed that the configuration for which this maximum lift coefficient was measured was very nearly the optimum. Maximum lift coefficients were shown to increase with Reynolds number for all deflections except the best maximum lift deflection, at which a decrease in Reynolds number from 14 million to 3.5 million caused an increase of about 0.1 in maximum lift coefficient.

INTRODUCTION

At the request of the Army Air Forces, Air Technical Service Command, tests have been conducted in the two-dimensional low-turbulence tunnel and the two-dimensional low-turbulence pressure tunnel on a 37.5-inch-chord model of a wing section of the Republic XF-12 airplane. The model was equipped with a double slotted flap which was designed to operate with a variable position of the fore flap with respect to the flap. The section at the station represented by this model is intermediate between the Republic R-4,40-318-1 and R-4,40-413-.6 airfoils.

Tests included an investigation of flap and fore flap configurations for maximum lift, lift characteristics at several flap deflections for two flap paths, and flap and fore-flap loads. The effect of Reynolds number and standard leading-edge roughness on the lift and drag characteristics were determined for several configurations.

SYMBOLS

c	airfoil chord
α_o	section angle of attack
c_d	section drag coefficient
c_l	section lift coefficient
$c_{l_{max}}$	section maximum lift coefficient
c_{n_f}	flap normal-force coefficient, based on flap chord
$c_{n_{ff}}$	fore-flap normal-force coefficient, based on fore-flap chord
c_{c_f}	flap chord-force coefficient, based on flap chord
$c_{c_{ff}}$	fore-flap chord-force coefficient, based on fore-flap chord

c_{m_f} flap moment coefficient about flap reference point, based on flap chord

$c_{m_{ff}}$ fore-flap moment coefficient about fore-flap reference point, based on fore-flap chord

R Reynolds number

δ_f, δ_{ff} deflections of the flap and fore flap, respectively, measured from the wing chord line

x_{ff}, y_{ff} horizontal and vertical positions of the fore-flap reference point measured from the most rearward station of the wing slot in percent of c, positive to the rear and below, respectively

x_f, y_f horizontal and vertical positions of the flap reference point measured from the fore-flap trailing edge in percent of c, positive to the rear and below, respectively

MODEL AND METHODS

The model was constructed by the Republic Aviation Corporation to the ordinates given in table I. The flap alone had a chord equal to 0.238c and the fore flap alone had a chord equal to 0.092c. Figure 1 shows a sketch of the airfoil section, the flap, and the fore flap. The foreward portion of the model was constructed of laminated mahogany. The flap and the fore flap were constructed of aluminum alloy. The main wing section and the flap and fore flap were provided with flush pressure orifices at several stations along the midspan of the model.

Flap and fore-flap configurations for each of the flap paths are shown in figure 2. The second path was designed by the contractor to provide low operating loads and will be referred to as the modified flap path. The 60° configuration shown for the original flap path is the position found to give the highest maximum lift. Lift and drag tests were made by the methods described in reference 1. Pressure distributions were read directly from a multiple-tube manometer connected to the model pressure orifices. The orifices were filled with glazing putty for all but the pressure-distribution tests. Because of time limitations it was necessary to run both the lift and pressure-distribution tests for the modified flap path concurrently.

Data were corrected to free-air values by the following equations in which the primed quantities represent values measured in the tunnel.

$$c_d = 0.974 c_d'$$

$$c_l = 0.938 c_l'$$

$$\alpha_o = 1.036 \alpha_o'$$

A complete discussion of these corrections as applied to data obtained in the two-dimensional low-turbulence tunnels is contained in reference 1.

Flap and fore-flap loads were obtained from integrations of pressure-distribution diagrams. The large amount of pressure-distribution data obtained is not presented.

RESULTS AND DISCUSSION

Lift.- An investigation was first carried out to determine which of several configurations of the flap and fore flap would provide the best maximum lift characteristics. A configuration which was considered good was set up and systematic variations of the various parameters were investigated. The values of these parameters for the original configuration are shown in the following table:

$\delta_{ff} = 25^\circ$	$\delta_f = 60^\circ$
$x_{ff} = -0.24$	$x_f = -2.5$
$y_{ff} = 2.0$	$y_f = 1.5$

The effect of fore-flap deflection is shown in figure 3(a). Fore-flap deflections of 20°, 25°, and 30° were investigated, all other parameters being kept constant. These results show that using a fore flap deflection higher than 25° would cause an appreciable decrease in the maximum lift. Changes in the position of the flap and fore flap as a unit were then investigated. The maximum lift coefficients are plotted in figure 3(b) as a function of the horizontal and vertical positions of the fore-flap reference point. The highest maximum lift was obtained with the fore-flap reference point 2 percent below and 0.5 percent behind the trailing edge of the main wing section. The fore flap was then held at this position and the flap rotated about its reference point. The lift characteristics at flap deflections of 55°, 60°, and 65° are shown in figure 4(a). The maximum lift is shown to increase gradually with flap deflection but the lift curve obtained at 65° shows a small break at about 0° angle of attack. The flap deflection was therefore limited to 60°. With the fore flap at its best position and the flap and fore-flap deflections at 60° and 25°, respectively, the flap position was varied. Maximum lift values are plotted against the flap position parameters x_f and y_f in figure 4(b). The highest maximum lift obtained was 3.56 with the flap 2 percent below and 1.5 percent forward of the fore-flap trailing edge. It is realized that this survey of flap and fore-flap configurations is not complete and that slightly higher values of maximum lift might be obtained by a more extensive investigation, but the final configuration is believed to be very near the optimum for maximum lift.

A comparison of figures 3 and 4 shows that generally this double slotted flap is more sensitive to changes in position and deflection of the fore flap than of the flap. A decrease of approximately 0.2 in maximum lift is caused by a 1 percent movement in either the vertical or horizontal directions from the best fore-flap position while a decrease of only 0.15 is caused by a total movement of 3 percent horizontally and 1.5 percent vertically from the best flap position.

Lift characteristics for the best flap configuration at several Reynolds numbers are shown in figure 5. The maximum lift is shown to decrease from 3.56 at a Reynolds number of 3.5 million to 3.43 at 14 million. It should be noted that the optimum position was found at a Reynolds number of 3.5 million. The optimum position at other Reynolds numbers might be slightly different.

Lift characteristics for flap deflections of 0°, 20°, 40°, and 60° are shown in figure 6 for the original flap path at Reynolds numbers of 3.5 and 14 million in the smooth condition and with standard leading-edge roughness for the higher Reynolds number. Figure 7 shows the lift characteristics at several flap deflections for the modified flap path. Data for this flap path were obtained only at a Reynolds number of 3.5 million and the maximum lift values may be slightly low because of slight surface irregularities at the open pressure orifices. Values of the maximum lift are shown in figure 8 plotted against flap deflection for each of these conditions. The effect of increasing the Reynolds number is shown to be favorable for all but the best maximum lift configuration and the effect of roughness is shown to be less on the best maximum lift configuration than on any other. A comparison of the three sets of lift data in figure 6 shows that at the low flap deflections the scale effect is confined to the maximum lifts while at the higher deflections the whole lift curve is shifted downward by an increase in Reynolds number. In most cases the roughness effects only the maximum lift. The fact that the curves of maximum lift against flap deflection for the original flap path are irregular and peak rather sharply at a deflection of 60°, particularly at a Reynolds number of 3.5 million can be explained by the fact that, at this deflection, the flap and fore flap are at, or very near their optimum configurations while at other deflections, their configurations are determined by the flap retracting mechanism.

Drag.- Figure 9 shows the drag characteristics of this airfoil section with flap retracted at Reynolds numbers of 3.5 and 14 million and at 14 million with standard leading-edge roughness. A comparison of the data in this figure with data previously obtained on other almost similar airfoils at lower Reynolds numbers shows that the minimum drag of this section is slightly higher than that of the Republic R-4,40-318-1 airfoil but that the effect of roughness is considerably less. The difference in minimum drag in the smooth condition may be explained by the slight amount of unfairness at the flap and by the fact that the flap-airfoil joint was not sealed against the possibility of leakage. The increments in minimum drag caused by roughness are probably different because of the difference in Reynolds numbers.

Flap loads.- Normal force, chord force, and moment coefficients, respectively, of the flap and fore flap at various flap deflections for each of the flap paths are presented in figures 10 to 12. No load data are shown for the fore flap at the 20° flap deflection with the original flap path, since, at this configuration, the fore flap is completely stalled.

No uniform variation in the load characteristics with flap deflection could be expected, because of the radical changes in the air passages around the flap and fore flap that occur as the flap deflection is changed. The unusually high negative fore-flap chord forces at the 20° flap deflection with the modified flap path are caused by the fact that rather high leading-edge velocities occur simultaneously with low velocities over the rear portion of the fore flap. No conclusion may be drawn as to whether the modified flap path presents more favorable load characteristics for this particular design than the original path since this would involve an analysis of the linkages to be used in the retracting mechanism. It should be noted that a maximum normal-force coefficient of the order of 5.0 is obtained on the fore flap. Care must be taken in the design of the fore flap and its fittings to make a structure sufficiently rigid to maintain the tolerances shown to be necessary in figures 3 and 4.

CONCLUDING REMARKS

A 37.5-inch-chord model of a wing section of the Republic XF-12 airplane, equipped with a double slotted flap, was tested in the Langley two-dimensional low-turbulence tunnels. A flap configuration was developed which is believed to be very near the optimum for maximum lift and which provided a maximum lift coefficient of 3.43 at a Reynolds number of 14 million. The maximum lift for all deflections except the best maximum lift configuration was shown to increase with Reynolds number. The maximum lift coefficient for the optimum configuration is shown to be approximately 0.10 higher at 3.5 million than at 14 million.

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REFERENCE

1. Abbott, Ira H., von Doenhoff, Albert E., and Stivers, Louis S., Jr.: Summary of Airfoil Data. NACA ACR No. L5C05, 1945.

TABLE I

ORDINATES FOR WING, FLAP, SLOT, AND FORE FLAP
[Stations and ordinates given in percent of wing chord]

Wing Section

Station	Upper surface	Lower surface
0	0	0
.50	1.627	1.040
.75	1.966	1.312
1.25	2.486	1.723
2.50	3.446	2.454
5.00	4.795	3.448
7.50	5.801	4.123
10.00	6.611	4.651
15.00	7.854	5.430
20.00	8.772	5.953
25.00	9.454	6.307
30.00	9.924	6.513
35.00	10.223	6.627
40.00	10.361	6.619
45.00	10.329	6.526
50.00	10.124	6.289
55.00	9.764	5.958
60.00	9.217	5.537
65.00	8.508	5.011
70.00	7.660	4.408
75.00	6.668	3.715
80.00	5.545	2.976
85.00	4.315	2.195
90.00	2.987	1.414
95.00	1.531	.680
100.00	.019	.019

L.E. radius: 1.830
Slope of radius through L.E.: 0.133

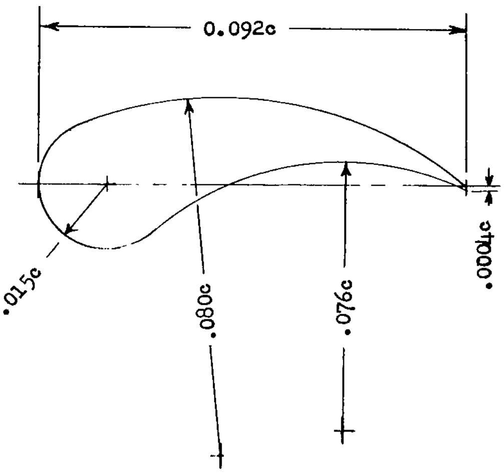
Flap

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
77.330	1.101	77.330	2.832
78.516	1.979	78.516	3.022
80.887	2.976	79.773	3.011
83.258	3.491	80.000	2.976
85.627	3.662	85.000	2.195
86.814	3.616	90.000	1.414
88.128	3.408	95.000	.680
90.000	2.987	100.000	:019
95.000	1.531		
100.000	.019		

L.E. radius: 1.912
L.E. radius below wing chord line: 0.925
L.E. radius aft of wing L.E.: 78.058

Slot

Station	Ordinate
69.377	-4.480
69.377	-2.419
69.625	-1.363
69.923	-.824
70.219	-.451
70.812	.107
71.404	.544
72.590	1.269
73.774	1.838
76.146	2.678
78.516	2.958
80.887	3.598
83.256	3.768
85.627	3.739
86.814	3.632
88.128	3.432



Fore Flap Dimensions

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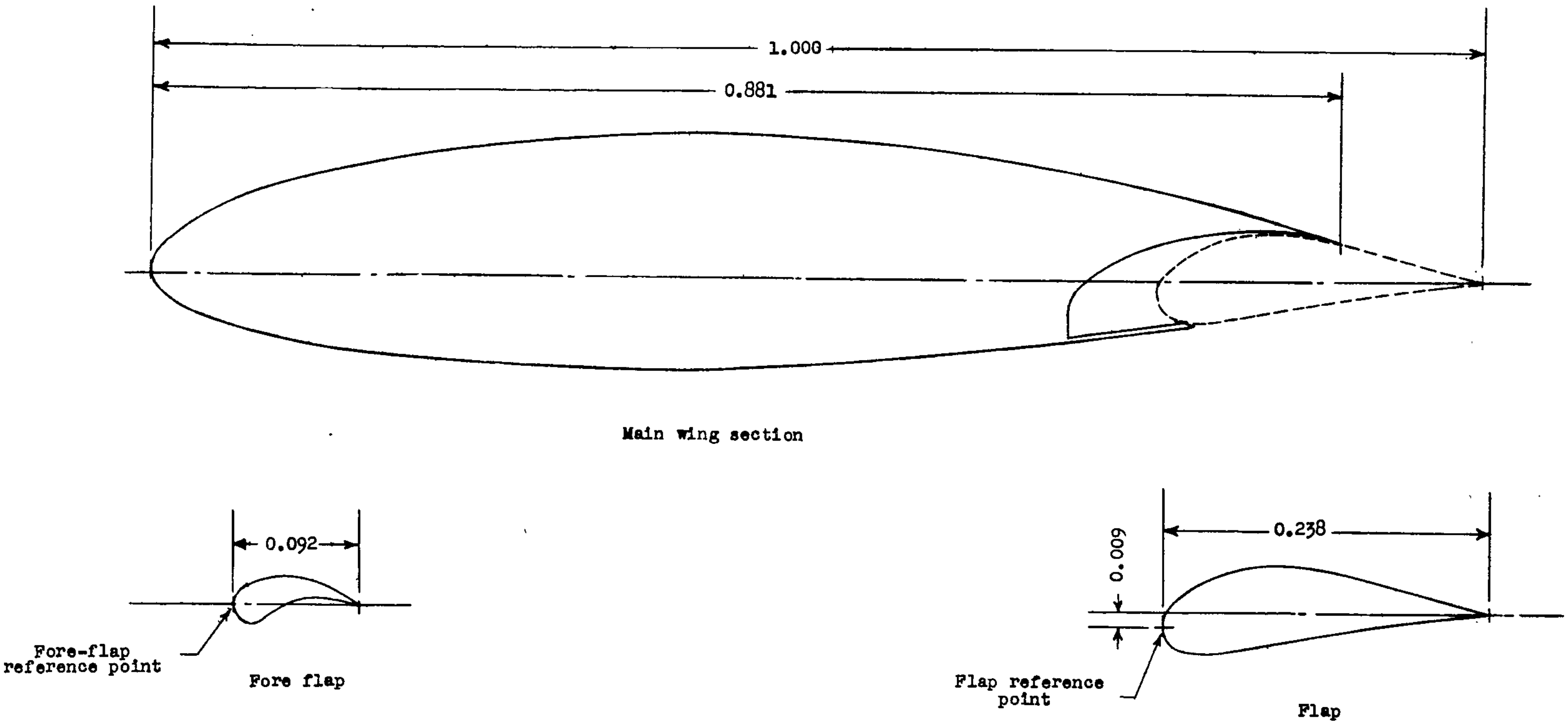

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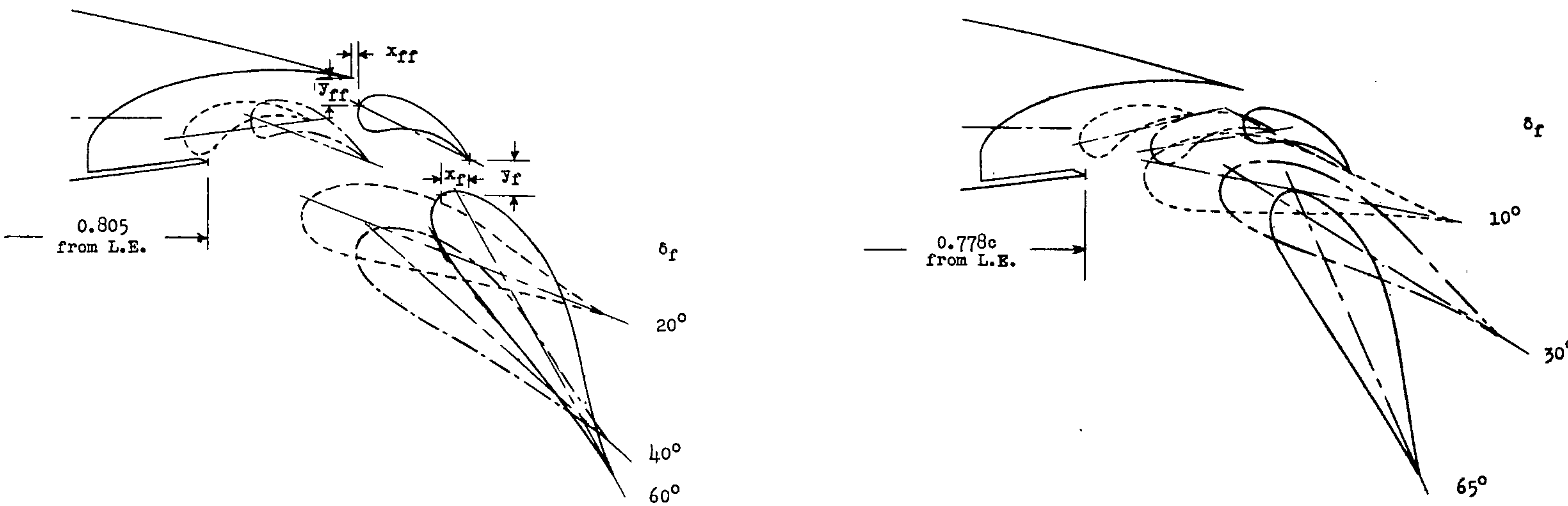
Figure 1 .- Wing, flap, and fore flap; double slotted flap model for Republic XF-12 airplane.



Original Flap Path

δ_f (deg)	x_f (percent c)	y_f (percent c)	δ_{ff} (deg)	x_{ff} (percent c)	y_{ff} (percent c)
20	0	6.00	-10	-13.24	4.66
40	0	5.06	20	-8.07	2.80
60	-1.5	2.00	25	.50	2.00

Modified Flap Path

δ_f (deg)	x_f (percent c)	y_f (percent c)	δ_{ff} (deg)	x_{ff} (percent c)	y_{ff} (percent c)
10	-4.05	3.79	-13	-13.04	4.09
20	-3.62	3.26	-8	-10.67	4.32
30	-3.62	2.84	-2	-7.53	4.40
40	-3.85	2.45	5	-4.80	3.90
65	-4.50	1.00	25	-.24	2.00

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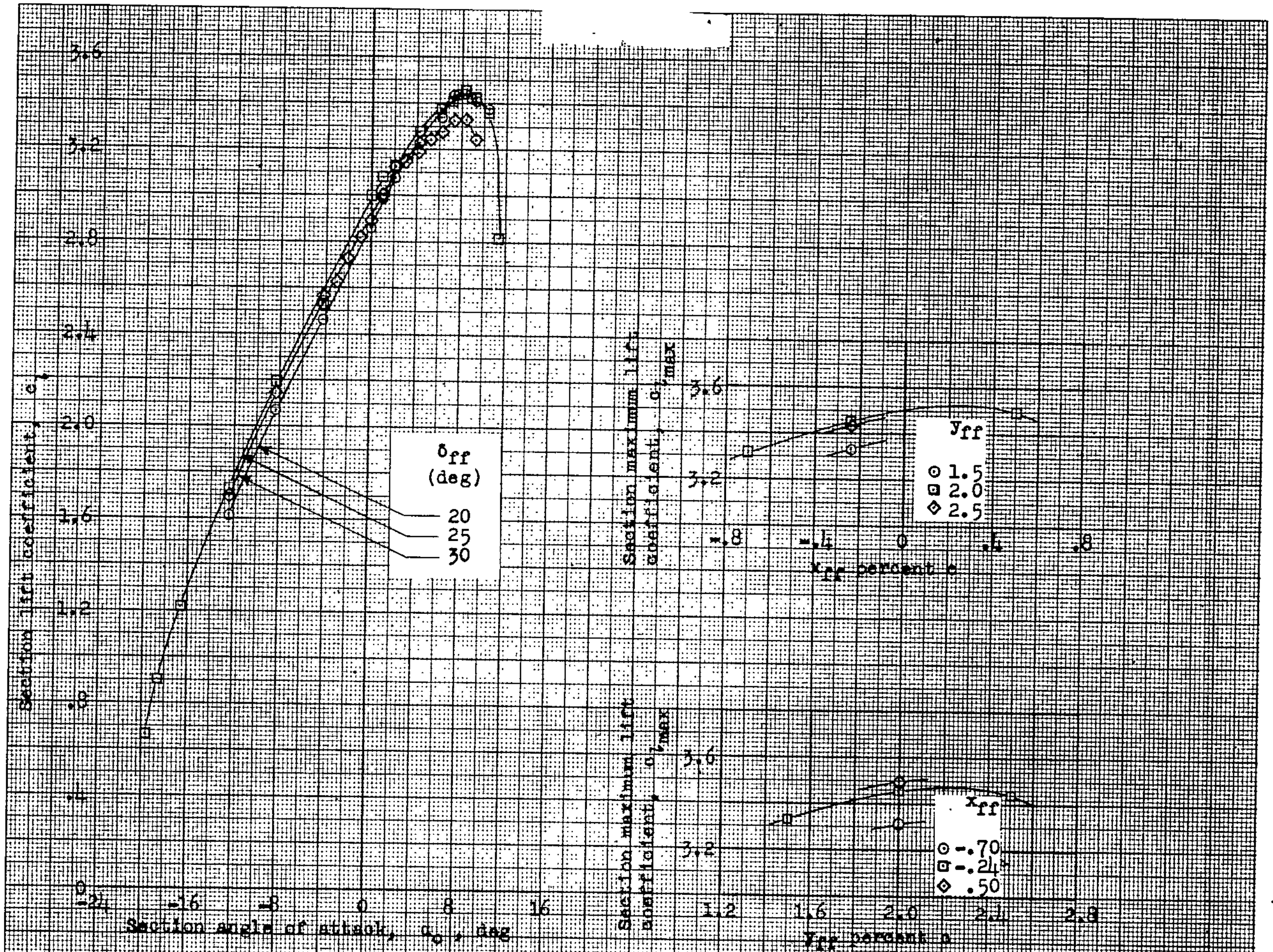
Figure 2 .- Flap and fore-flap configurations for flap paths tested.



(a) Effect of fore flap deflection. $x_{ff} = -0.24$; $y_{ff} = 2.0$

(b) Effect of fore flap position. $\delta_{ff} = 25^{\circ}$

Figure 3.- Effect of fore flap deflection and position on maximum lift. $\delta_f = 60^{\circ}$; $x_f = -2.5$; $y_f = 1.5$; $R = 3.5 \times 10^6$ (approx.)

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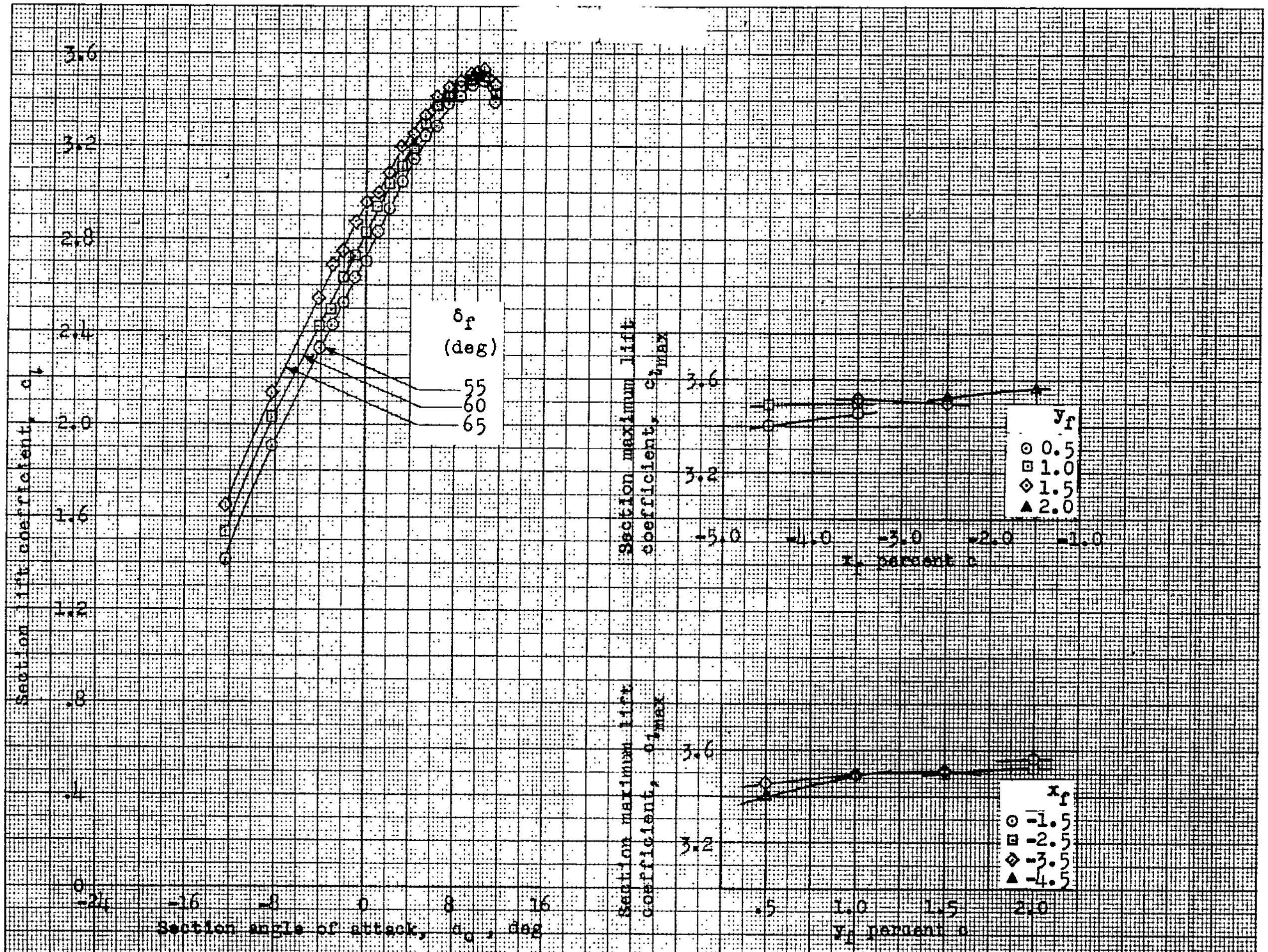

(a) Effect of flap deflection. $x_f = -2.5$; $y_f = 1.5$

(b) Effect of flap position. $\delta_f = 60^{\circ}$

Figure 4.- Effect of flap deflection and position on maximum lift. $\delta_{ff} = 25^{\circ}$; $x_{ff} = 0.50$; $y_{ff} = 2.0$; $R = 3.5 \times 10^6$.

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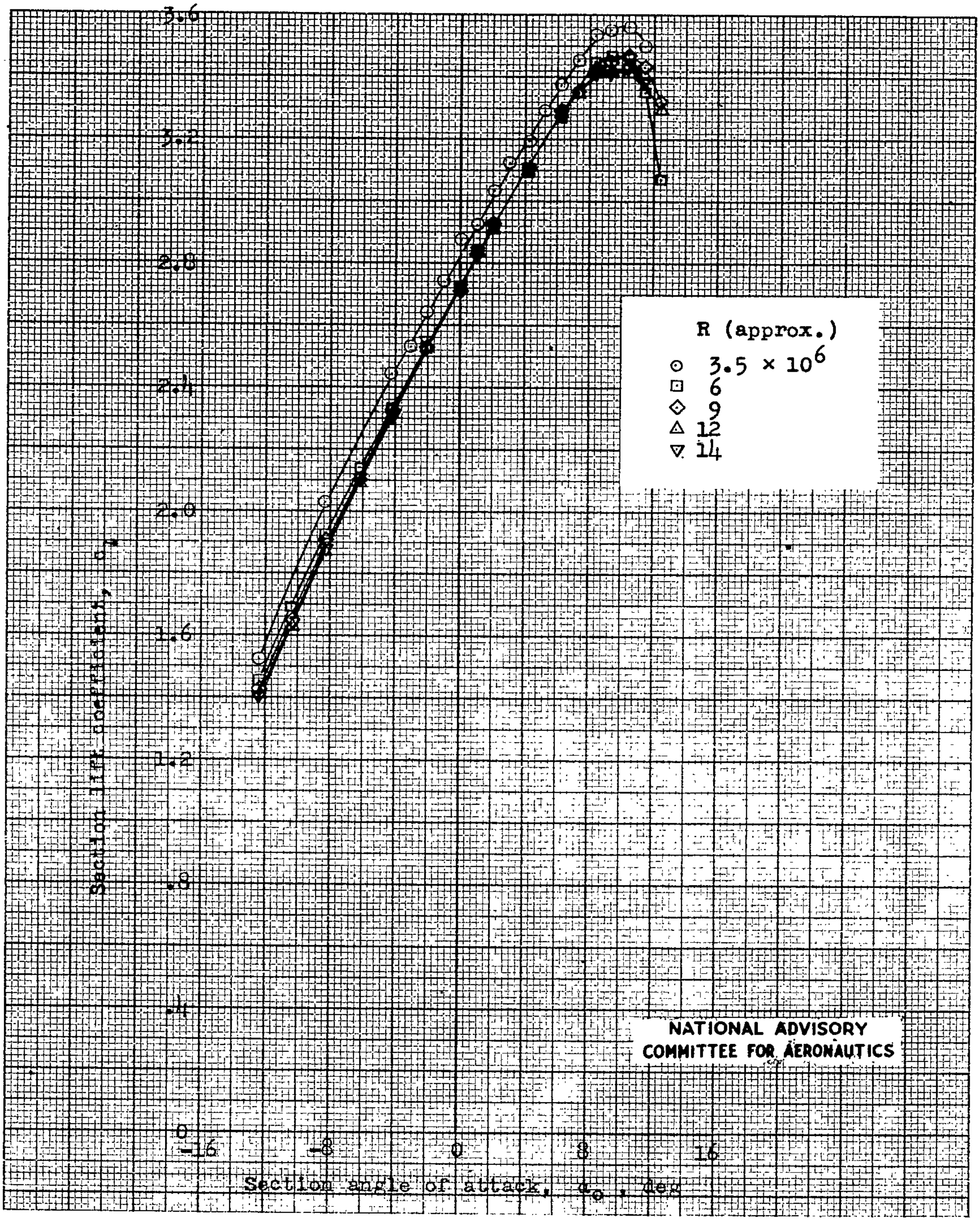
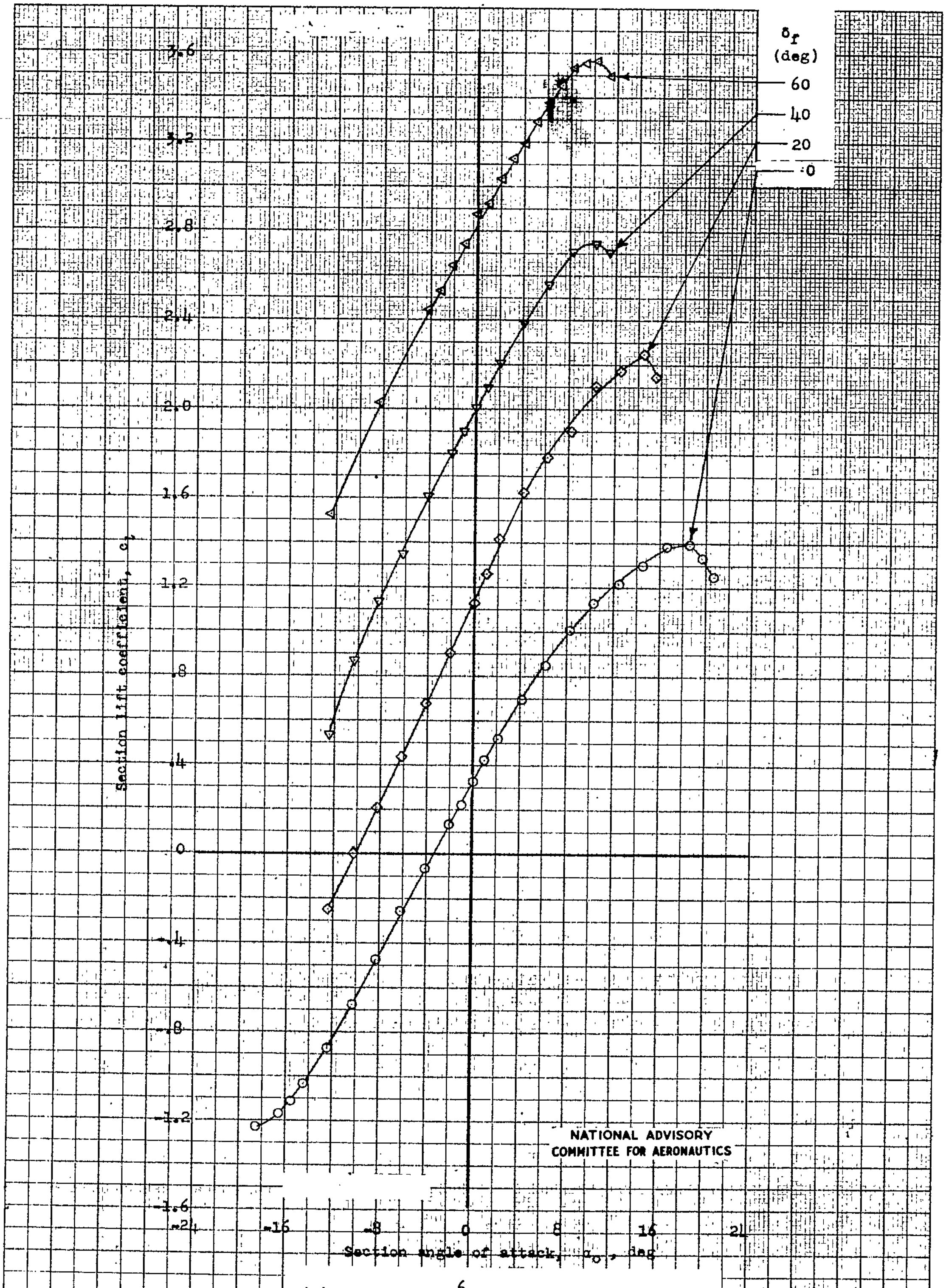
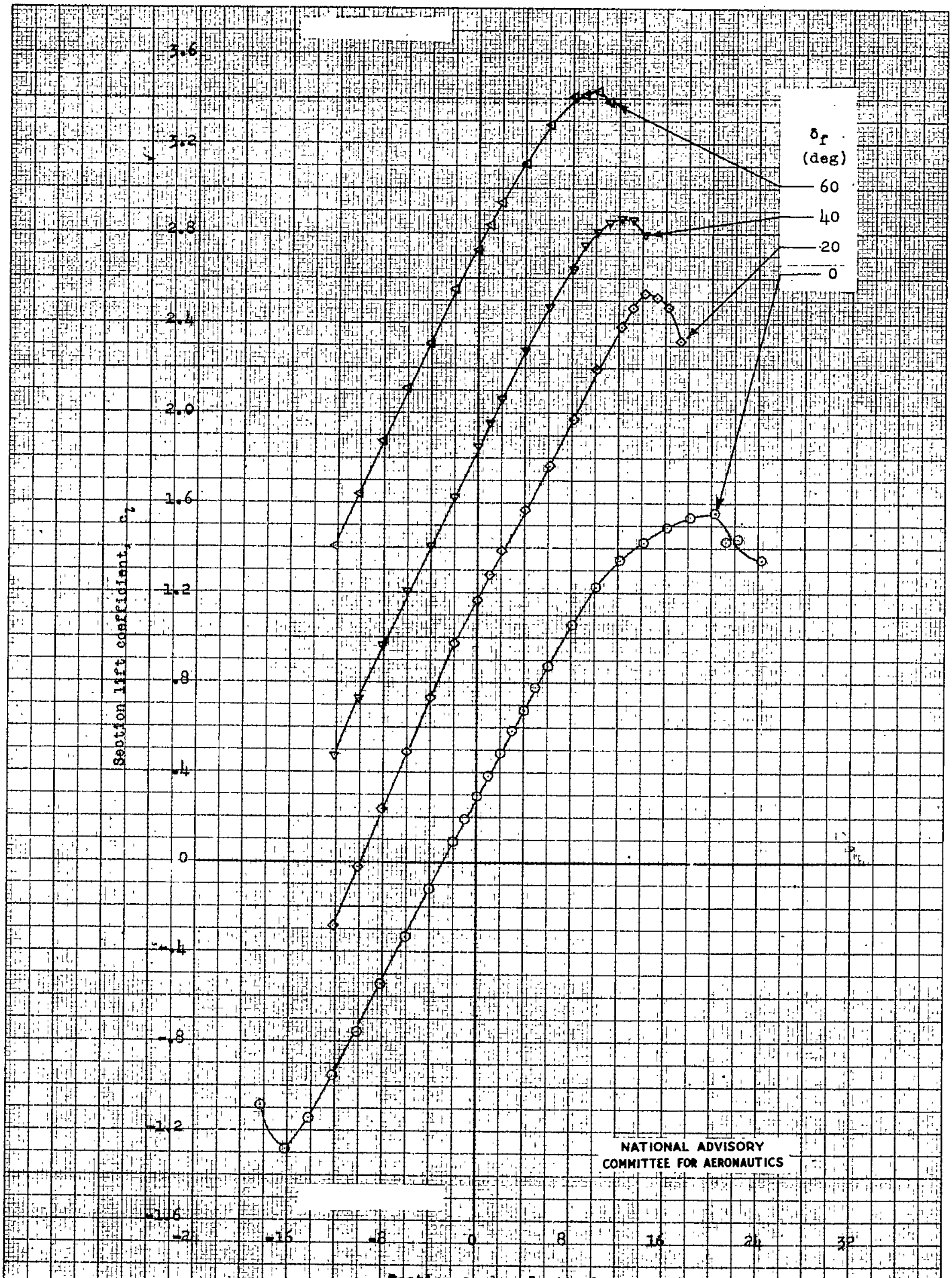


Figure 5 .- Lift characteristics of a wing section of the Republic XF-12 airplane equipped with a double slotted flap at various Reynolds numbers. Optimum maximum lift configuration; $\delta_f = 60^\circ$; $x_f = -1.5$; $y_f = 2.0$; $\delta_{ff} = 25^\circ$; $x_{ff} = .5$; $y_{ff} = 2.0$.



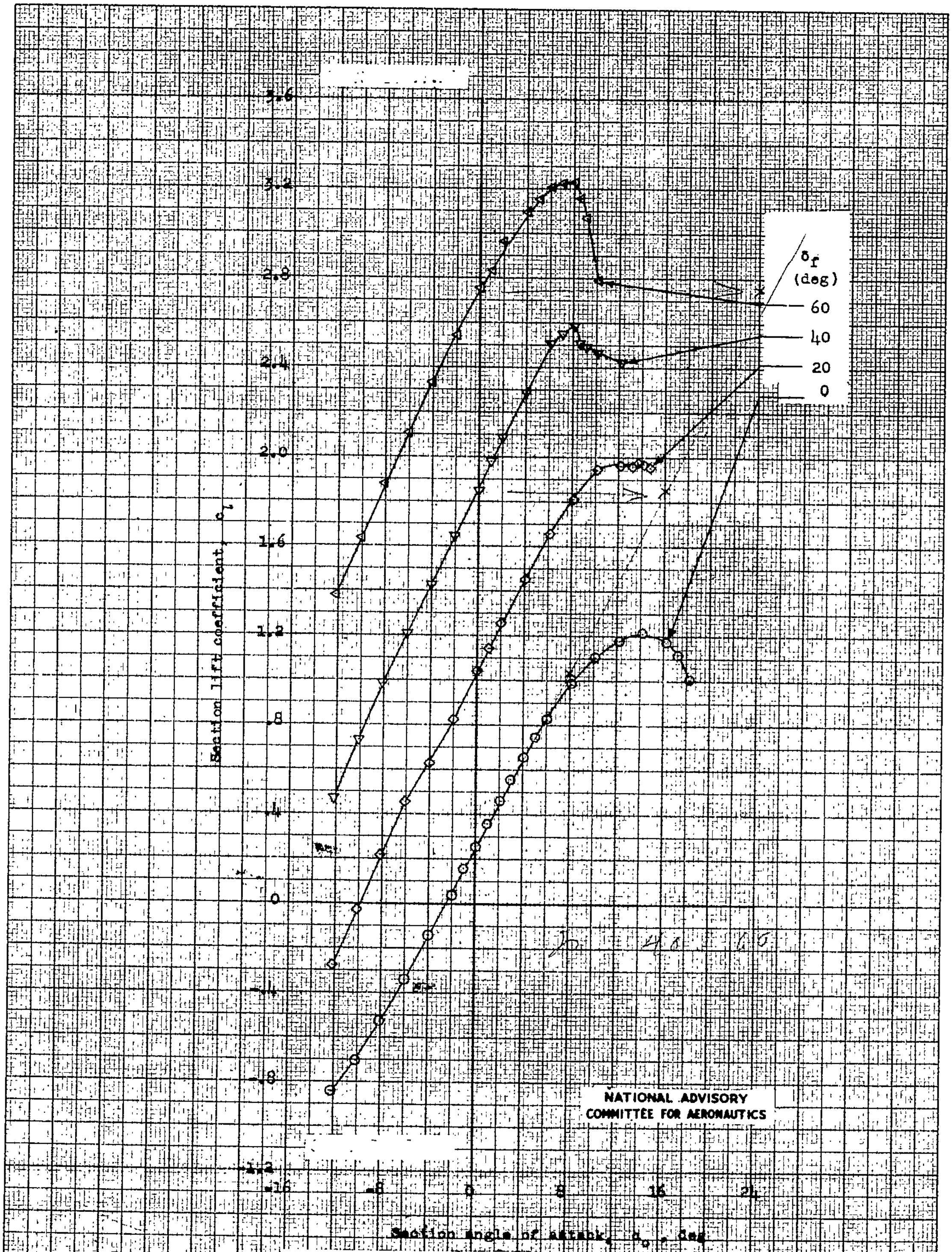
(a) $R = 3.5 \times 10^6$ (approx.); surface smooth

Figure 6 .- Lift characteristics of a wing section for the Republic XF-12 airplane equipped with a double slotted flap. Original flap path.



(b) R = 14 × 10^6 (approx.); surface smooth

Figure 6 .- Continued.



(c) R = 14 × 10^6 (approx.); standard leading-edge roughness

Figure 6 .- Concluded.

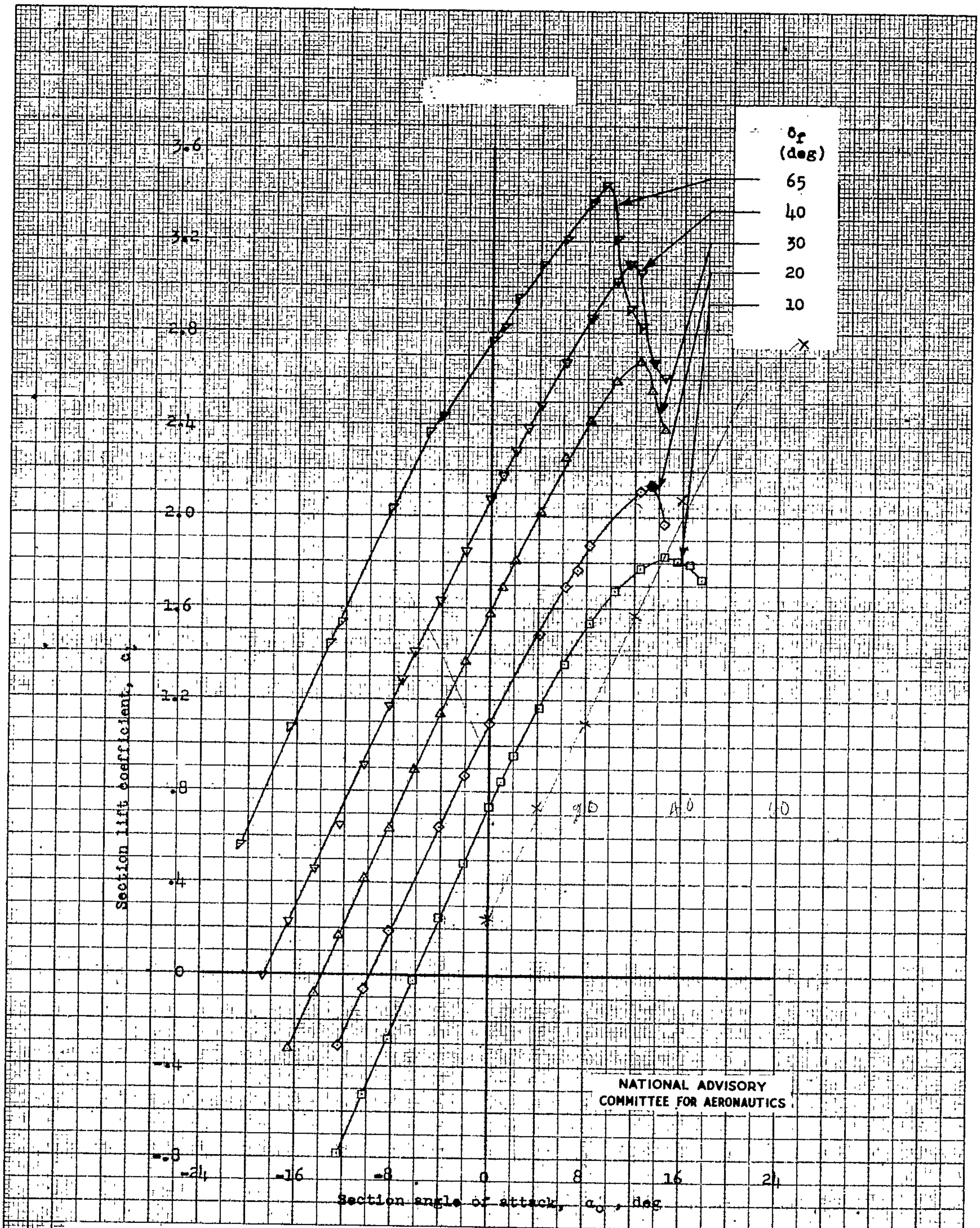


Figure 7 .- Lift characteristics of a wing section for the Republic XF-12 airplane equipped with a double slotted flap. Modified flap path. $R = 3.5 \times 10^6$ (approx.).

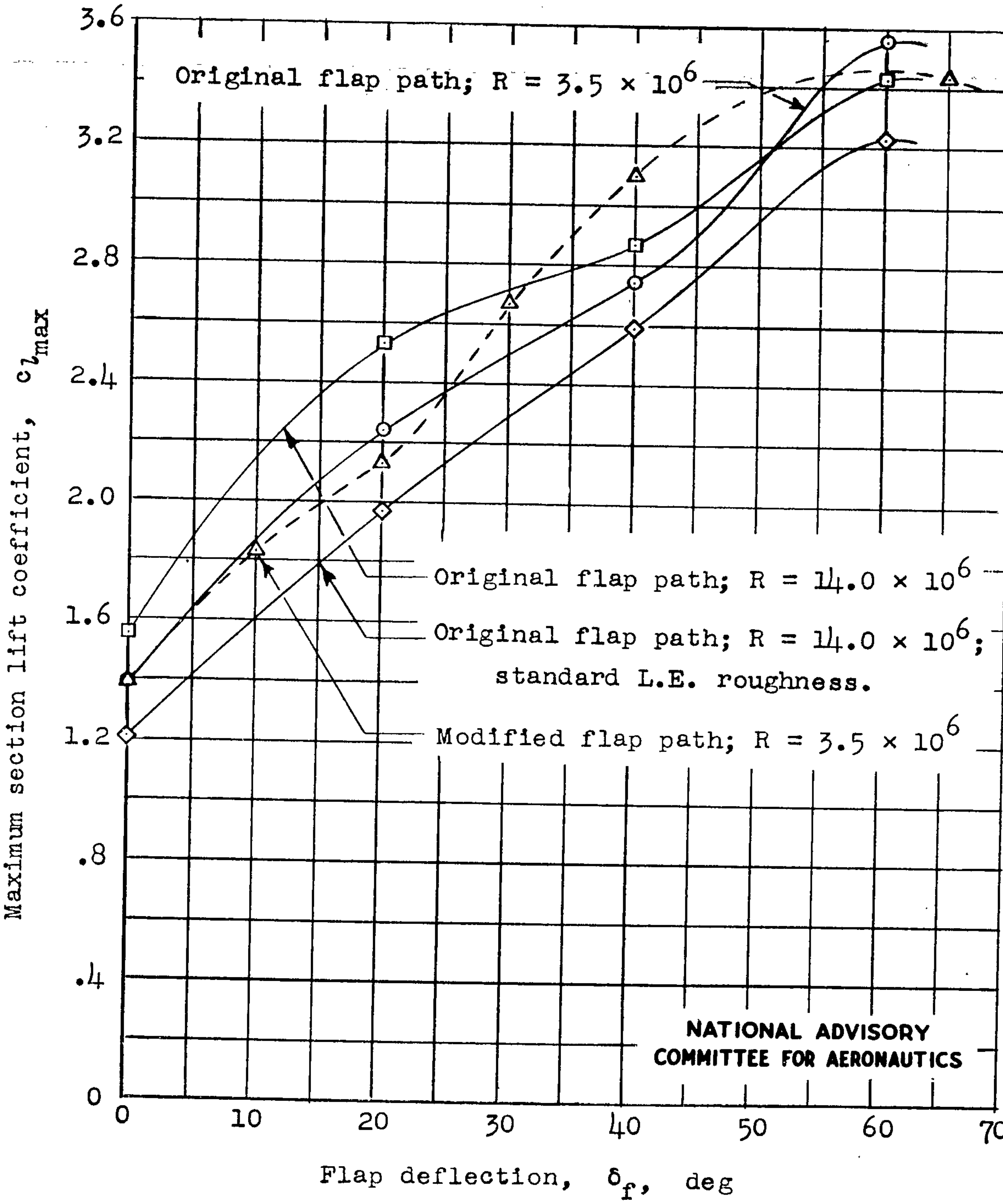


Figure 8.- Maximum section lift coefficients at various flap deflections for both flap paths.

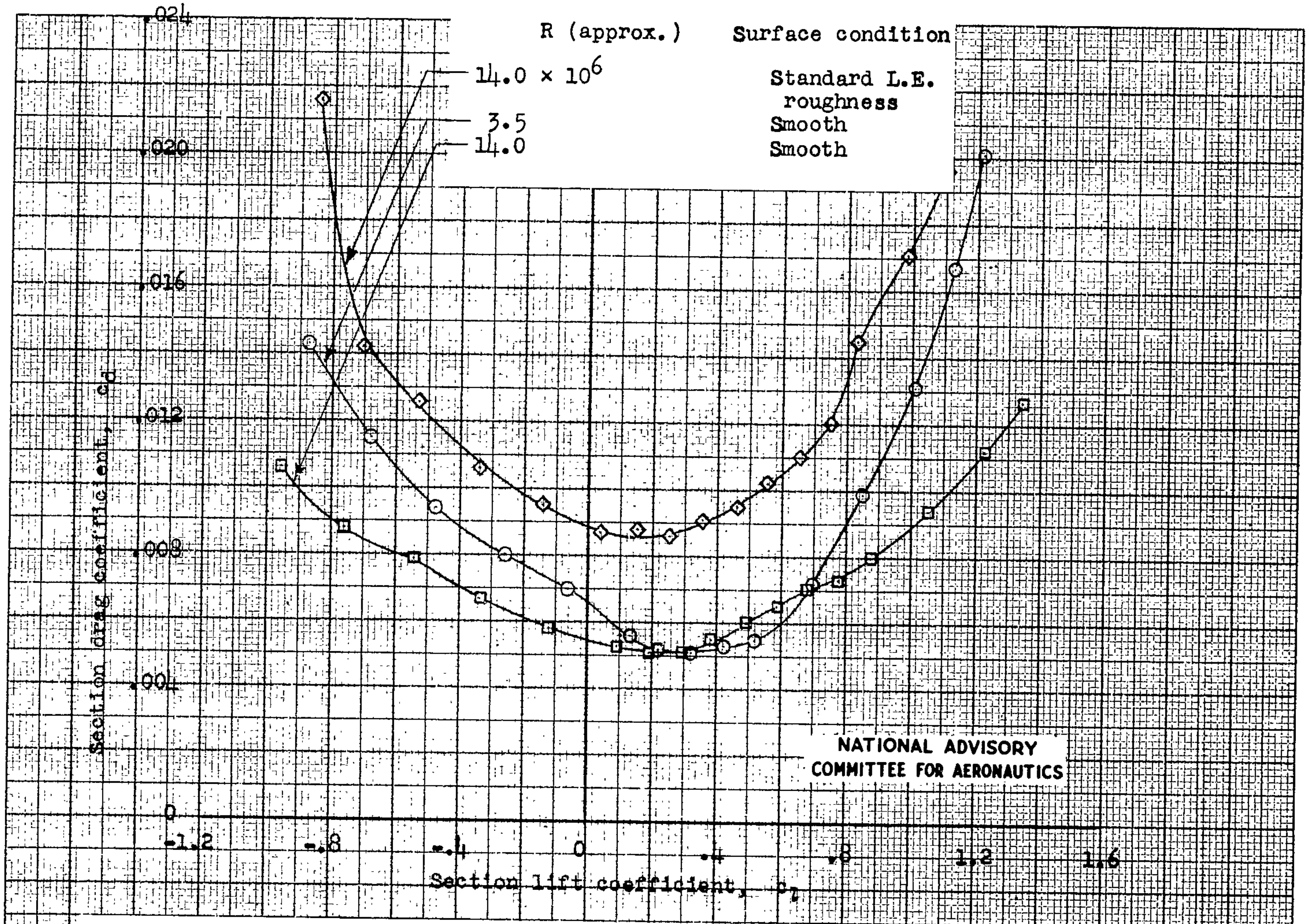


Figure 9 .- Drag characteristics of a wing section for the Republic XF-12 airplane. Flap retracted.

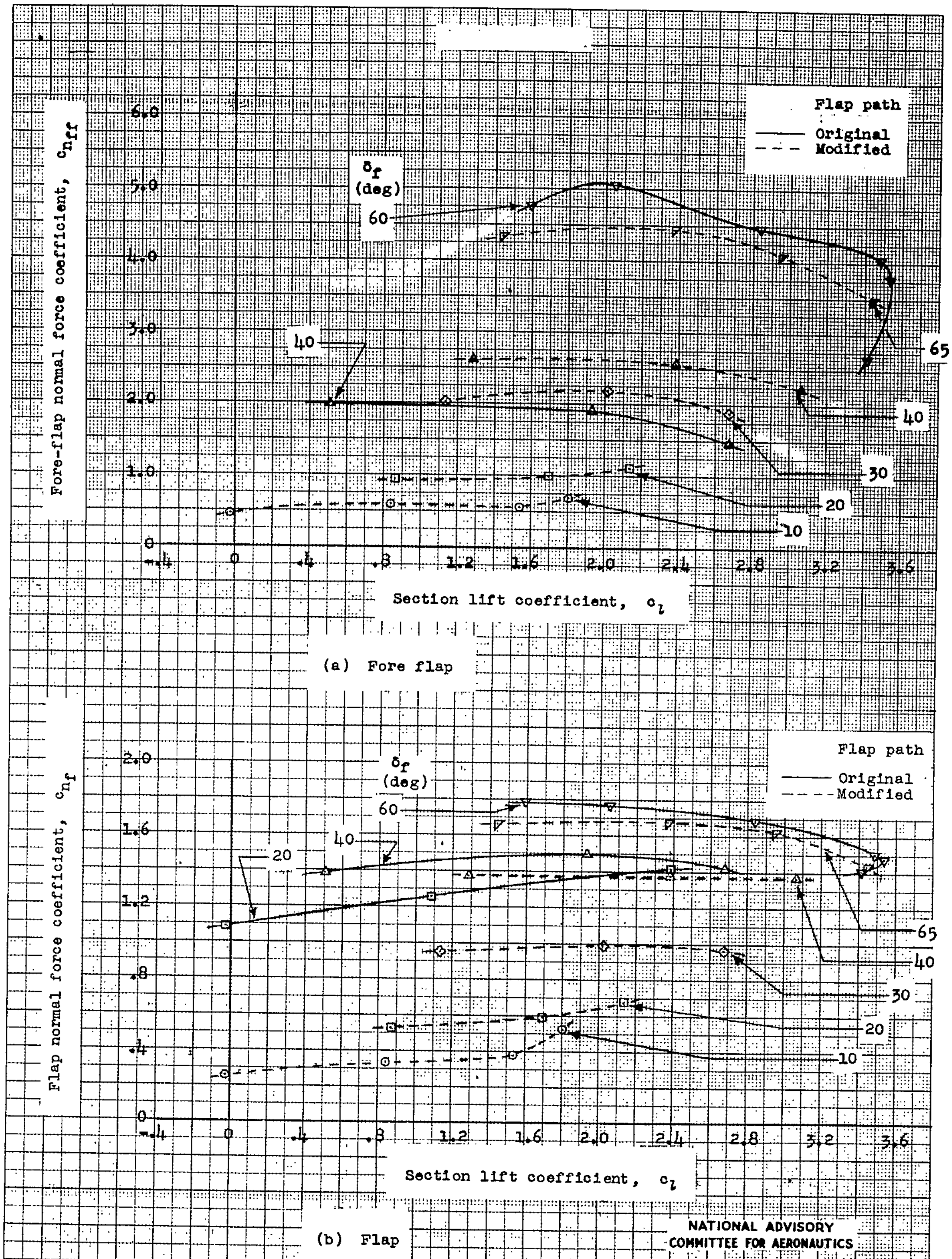


Figure 10.- Normal force coefficients of flap and fore flap for wing section of the Republic XF-12 airplane.

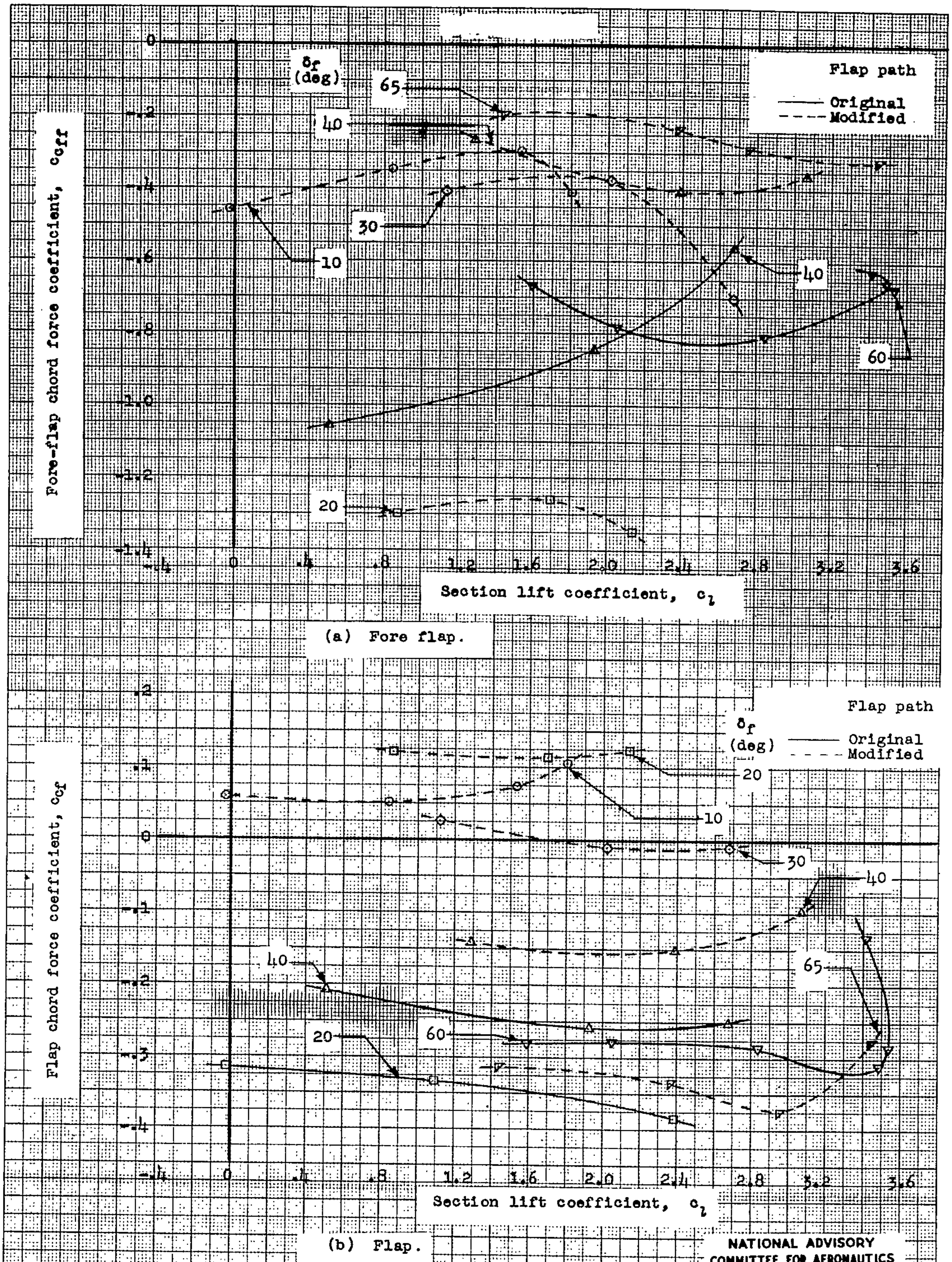


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Figure 11 .- Chord force coefficients of flap and fore flap for wing section of the Republic XF-12 airplane.

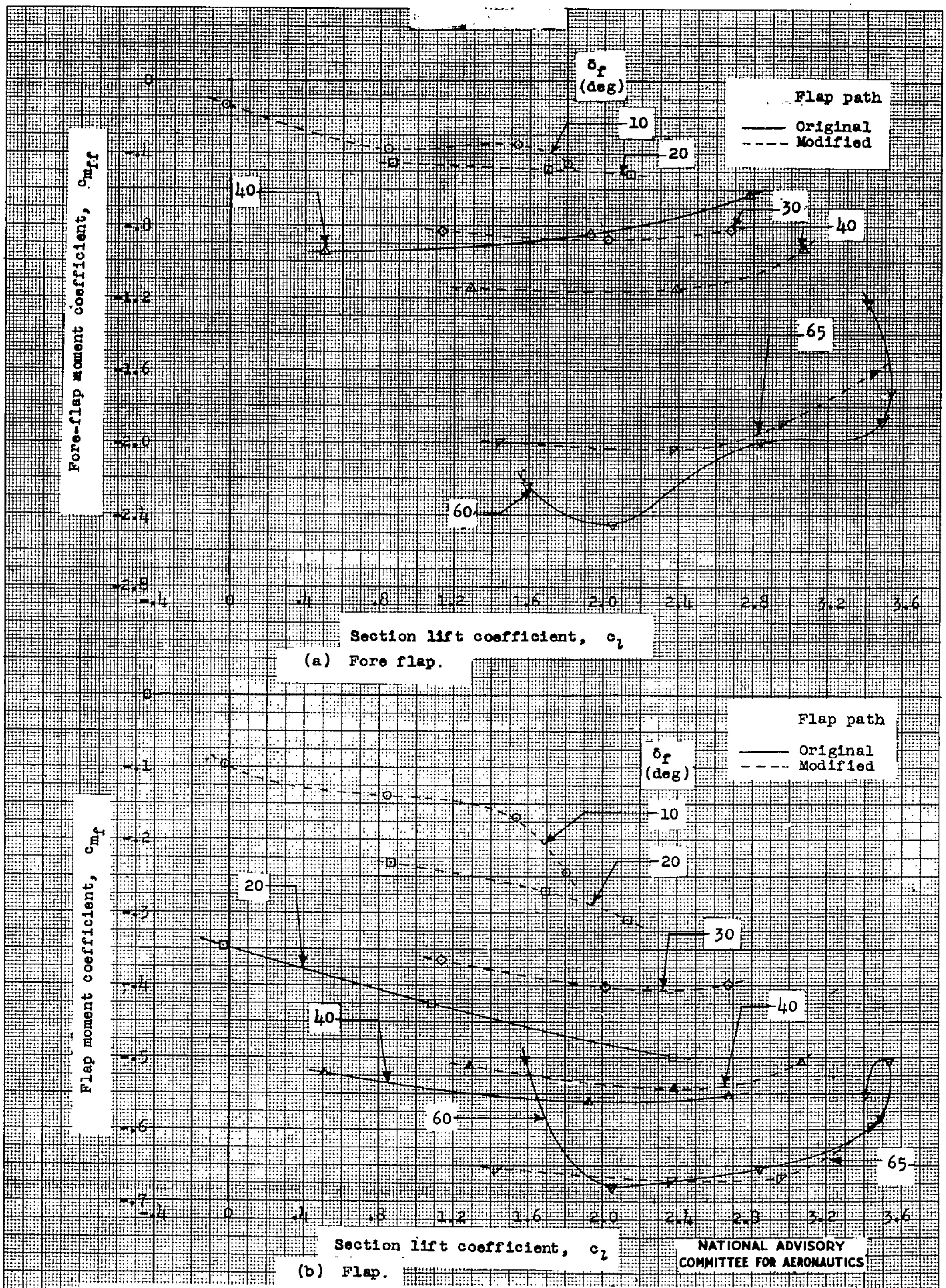

Figure 12.- Moment coefficients of flap and fore flap for wing section of the Republic XF-12 airplane.